PROCUREMENT OF COMMERCIAL OFF-THE-SHELF COMPUTER EQUIPMENT FOR USE IN NAVY COMMAND, CONTROL, COMMUNICATIONS AND INTELLIGENCE SYSTEMS

A thesis presented to the Faculty of the U.S. Army Command and General Staff College in partial fulfillment of the requirements for the degree

MASTER OF MILITARY ART AND SCIENCE

by

HERBERT YEE, LCDR, USN
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ABSTRACT

PROCUREMENT OF COMMERCIAL OFF-THE-SHELF COMPUTER EQUIPMENT FOR USE IN NAVY COMMAND, CONTROL, COMMUNICATIONS AND INTELLIGENCE SYSTEMS by LCDR Herbert Yee, USN, 93 pages

This study investigates the procurement of commercial off-the-shelf (COTS) computers for use in Navy Command, Control, Communications and Intelligence (C3I) systems.

The procurement policy was reviewed from 1970 to the present to determine what changes were effected to improve the procurement process. Then, a case study was conducted which analyzed the Flag Data Display System (FDDS) and Joint Operational Tactical System I (JOTS I). The two systems were compared to determine if the JOTS I procured under the new policy better supported the operational requirements of the tactical commander at sea than the FDDS.

The conclusions revealed that the DOD procurement process was streamlined for the better and the use of COTS shortened the acquisition cycle and reduced research and developmental costs. The comparative analysis of FDDS and JOTS I demonstrated that JOTS I was not operationally effective and suitable in meeting the tactical commander's requirements.

It was recommended that with the reshaping of the military, further studies should be conducted on how to better use Navy C3I systems in operations other than war to include joint operations.

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CHAPTER ONE

INTRODUCTION

Importance of the Study

A command, control, communications and intelligence (C3I) system is the most important means by which a Navy tactical commander controls/executes authority over his forces. Effective C3I enables the tactical commander to adequately visualize the disposition of his forces, address the tactical problem in proper perspective, and respond with a rational and intelligent decision.

The tactical commander afloat requires a C3I system that can assimilate the necessary information quickly and accurately which then enables the commander to make a decision and disseminate orders to subordinate commanders. Further, the quality and capability of the systems must adhere to stringent standards to ensure the commander receives accurate information. A C3I system containing deficiencies can severely impair the tactical commander's decision making capability and possibly be detrimental to the mission. To ensure the commander has an effective C3I system, the Navy has established a program to evaluate a system's operational effectiveness and suitability to support the tactical commander afloat. The Commander,

Operational Testing and Evaluation Force (COMOPTEVFOR), has the responsibility to test and evaluate C3I systems to determine whether standards are met.

The C3I systems presently in the fleet are obsolete when compared to the complex and sophisticated weapons systems that generate the combat power required to destroy the enemy. Additionally, advanced technology has enabled the military to build sophisticated intelligence collecting devices that produce an inordinate amount of tactical information that can overwhelm the tactical commander. Yet, the C3I systems that gather, process, and display this information are not of the same caliber. The Navy must narrow this technology gap between C3I systems and weapons systems by placing greater emphasis on developing improved C3I systems.

In the present state of budget reductions, the Navy must ensure that it is getting the best for its money without compromising the stringent military standards in system performance. Because the C3I system represents the tactical commander's nerve center, it is an absolute necessity that the commander's C3I system has the sophistication to manage the data.

The Statement of the Problem

This research proposed to evaluate the operational effectiveness and suitability of commercial off-the-shelf

(COTS) computer equipment acquired under the new procurement policy for nondevelopmental items (NDI) to meet the Navy's requirements for a tactical Command, Control, Communications and Intelligence (C3I) system afloat. The focus of the research was a historical analysis of procurement policy and a comparative analysis of two tactical C3I systems afloat: one procured under the old acquisition policy and one procured under the current policy.

The Hypotheses

1. The first hypothesis was that the new Department of Defense (DOD) procurement policy is better than the old one in terms of streamlining the acquisition cycle and reducing associated costs.

2. The second hypothesis was that COTS computer equipment employed in a tactical environment to support the Naval Commander afloat meets his operational requirements but does not meet the standards promulgated in the Test and Evaluation Master Plan.

The Subproblems

1. The first subproblem was to determine the differences in DOD's current procurement policy in comparison to the former.

2. The second subproblem was to determine the operational effectiveness and operational suitability (i.e. reliability, availability, and maintainability) of the COTS

computer equipment when compared to a system designed to meet military specifications (mil-specs) for the naval commander's C3I requirements in a tactical environment.

Limitations

This study addressed two types of C3I systems installed in conventional and nuclear powered aircraft carriers (CV & CVN). One C3I system type designed to military specifications was the Flag Data Display System (FDDS); the second Joint Operational Tactical System (JOTS) used a commercial desktop computer.

Both systems addressed in this study perform information gathering, processing, display and dissemination in support of the naval commander afloat.

The operational evaluation (OPEVAL) reports provided the tool to compare the two systems.

Delimitations

This study did not address systems integrated with weapons systems.

This study did not address C3I systems installed - aboard US submarines or aircraft.

This study did not address C3I systems prior to 1970.

This study did not address software procurement policies.

This study did not use threat assessment reports (secret level) to evaluate the threat(s).

The study did not address the different modes of communications (i.e., radio, satellite) associated with C3I systems.

Definitions

Commercial Item Description (CID). A commercial item description is a specification that describes, by salient functional or performance characteristics, the available, acceptable commercial or commercial-type products that will satisfy government needs. It is a type of federal specification.[1]

Carrier Intelligence Center (CVIC). A secure compartmented space aboard a conventional or nuclear aircraft carrier where intelligence information is gathered, processed and assimilated for battle group use.

Combat Direction Center (CDC). The secure compartment aboard a conventional or nuclear aircraft carrier from which the commander controls the defense of the aircraft carrier.

Command and Control (C2). The exercise of authority and direction by a properly designated commander over assigned forces in the accomplishment of his mission. C2 functions are performed through an arrangement of personnel, equipment, communications, facilities and procedures which are employed by a commander in planning, directing, coordinating, and controlling forces and operations in the accomplishment of his mission.[2]

Command, Control, Communications and Intelligence (C3I) system. Any automated computer system that collects, fuses, exchanges data and displays it for a tactical commander to interpret and make an informed decision.

Commercial off-the-shelf (COTS). "Products in regular production sold in substantial quantities to the general public and/or industry at established market or catalog prices."[3]

Electromagnetic pulse (EMP). "Current and voltage surges triggered by a nuclear blast above the earth's surface."[4]

Flag Data Display System (FDDS). A C2 system procured under the old procurement policy and installed in the Tactical Flag Command Center (TFCC), CDC, CVIC and Supplementary Plot (SUPPLOT) of both conventional and nuclear aircraft carriers to support the tactical commander afloat.

Joint Operational Tactical System (JOTS). An interim C2 system procured under the new procurement policy and installed in the TFCC, CDC, CVIC and SUPPLOT of both conventional and nuclear aircraft carriers to support the tactical commander afloat.

Military specification. A military requirement that a weapons system must be able to perform under certain parameters.

Navy Tactical Data System (NTDS). A tactical computer installed onboard combat ships and some aircraft that enables communicating information such as position, course, speed and altitude to other NTDS equipped units.

Nondevelopmental Item (NDI). "To include items that are either available in the commercial marketplace or otherwise already developed and in use by a government entity in this or an allied country."[5]

Operational Evaluation (OPEVAL). The phase of operational testing and evaluation in which all known problems and deficiencies in developmental testing are corrected. These deficiencies included hardware and software related problems observed in the engineering and development of the system. Once all deficiencies are corrected, the program manager certifies a system as ready for OPEVAL. Favorable results and conclusions lead to a milestone III decision that recommends going into full production.

Operational testing and evaluation (OT&E). "Testing and evaluation conducted to estimate a system's operational effectiveness and operational suitability, identify needed modifications, and provide information on tactics, doctrine, organization, and personnel requirements."[6]

Officer in Tactical Command Information Exchange System (OTCIXS). A two-way satellite communications system for ashore and afloat units with satellite equipped

capability.

Prototype Ocean Surveillance Terminal (POST). A Hewlett Packard desktop computer developed to perform correlation of electronic intelligence (ELINT). It was installed as a subsystem to pre-process ELINT data prior to being forwarded into FDDS, Tomahawk Weapons Control System (TWCS) or JOTS.

Supplementary Plot (SUPPLOT). A secure compartmented space aboard a conventional or nuclear aircraft carrier in which special intelligence information is routed for initial processing. This was one of four locations in which a FDDS or JOTS terminal was installed.

Tactical environment. Includes both peacetime and wartime environment. Peacetime environment encompasses underway steaming under nonhostile conditions. Wartime environment encompasses underway steaming in which the threat of imminent attack by hostile forces is possible.

Tactical C3I system. "Those C3I systems and equipment which are developed and acquired for use by tactical forces."[7]

Tactical Flag Command Center (TFCC). The secure compartment in a conventional or nuclear aircraft carrier from which the embarked commander and his staff operated, and where they made tactical decisions. This was one of four locations in which a FDDS or JOTS system was installed.

Test and Evaluation Master Plan (TEMP). A document that provides overall guidance in the procurement of a system. The document typically describes the equipment characteristics, developmental and operational testing schedules, tentative milestone achievement dates, critical operational issues (test objectives) for evaluation and identifies resources required to conduct the testing.

Then Year Dollars. The value of current year dollars from years past.

Tomahawk Weapons Control System (TWCS). A shipboard cruise missile weapons system that included an integrated command and control suite. Its C2 system in functionality was very similar to FDDS. The SPRUANCE class destroyers and AEGIS class cruisers employ this system.

Weapons system. A generic term to describe any type of equipment (i.e. gun system, missile system, etc.) with the capability to launch a missile or fire a projectile.

Assumptions

1. The operational test and evaluation criteria were the same under the old procurement policy as in the new.

2. C3I computer equipment was tested in a realistic operational environment.

3. The computer technology used in the design phase was the state of the art for that era.

4. The threat discussed in the National Security Strategy of the United States[9] and Military Strategy of the

United States' accurately reflect the threat imposed on the country and dictates what weapons systems will be procured.

5. The budget constraints imposed on the military have required the Navy to change its method of weapons procurement.

6. Costs were either "current" or "then year" dollars.

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CHAPTER II

LITERATURE REVIEW

Historical Background

In 1972 the Commission on Government Procurement introduced the recommendation that the acquisition process of commercial items become the leading policy in developing new systems. In the ensuing years the DOD increased its awareness of using NDI and emphasized the need to follow this path of procurement to field systems more rapidly. This change in procurement policy did not occur overnight. Rather, it was an evolutionary process in which study groups, commissions and federal agencies studied, and restudied for two decades before producing a viable solution.

In the 1980's, the timing seemed appropriate in the political and military arenas for identifying alternative methods of military weapons systems procurement. During President Reagan's tenure he ordered two studies, one in 1983 by the Grace commission and the other in 1986 by the Packard commission (President's Blue Ribbon Commission on Defense Management) to investigate the defense acquisition system.[1] The Packard commission's report was the most comprehensive and accurate compared to those completed in

the past. The commission interviewed many experts and critics in the field concerning the various aspects of the current acquisition process. One of the major recommendations made by the Packard Commission was to expand the use of commercial products rather than develop items under military specifications.[2]

The literature reviewed for this study provided good general information on the C3I concept. As an example a book titled C3I: Issues of Command and Control, consolidated many excerpts from an extensive number of sources to provide an indepth look at all Command and Control issues.[3] This book ranged from a very broad overview to specific issues that included buying COTS items in order to shorten the procurement cycle. It also provided a historical perspective on the importance of C3I to commanders. Focusing closer on the thesis topic of Navy C2 systems, Kenneth Allard's book Command, Control and the Common Defense provided an excellent source of historical information and also discussed the TFCC and FDDS installed onboard aircraft carriers.[4]

NDI Technology

Loescher in "Navy Reshapes, Develops Copernicus Architecture,"[5] reviewed and discussed the latest innovations and advances in computer technology that support the development of improved C3I systems. Other authors[6] promoted the use of COTS items to support C3I. The testing

of new equipment in the controlled laboratory environment showed favorable results; however, no evidence exists that indicates the equipment tested would prove reliable in an operational environment.

An examination of the ideas and thoughts expressed by military researchers[7] suggested that the lead time between conceptualization and development was too long for systems procured under military specifications and standards. Additionally, insufficient attention was given to calculating long-term costs. In many cases the final costs were much higher than the original estimates. The recurring conclusions indicated that buying commercial off-the-shelf (COTS) items saved money and reduced the acquisition cycle.

Test and Evaluation (T&E)

The Navy required that all systems under procurement undergo rigorous testing and evaluation as part of the acquisition process. Testing was a time-consuming and costly effort, frequently delaying the introduction of an item needed by the fleet. A review of the Assistant Secretary of Defense's document Buying NDI[8], an Air Force research report[9], and an Army Science Board study[10] on procuring NDI for C3I indicate that buying NDI reduced the procurement time. The consensus was that if the vendor's testing was comparable to the military standards of testing, then the developmental testing was waivable.

Regardless of any savings gained in terms of money

and time, a Navy system under procurement must pass its final phase of testing before full production can begin: operational testing and evaluation (OT&E). In reviewing the Navy's operational assessment and test and evaluation reports[11] on C3I systems conducted over the last 12 years, I noted the reports provided detailed background information on each C3I system under evaluation. Additionally, the reports provided a chronology on the evolution of the system; insights in how the particular system evolved and came into being; a forecast of the project's future and program direction; and the follow-on scheduled milestones in the procurement process.

Above all, the most important facets of OT&E were the published results, conclusions and recommendations which determined whether the Navy's requirements for a system were satisfactorily met and whether the system was ready for introduction into the fleet.

Military Specifications (Mil-spec)

When discussing COTS items, the frequently asked question was whether an item conformed to mil-spec and/or military standards (mil-std). Mil-spec is of great concern and draws interest in the military and commercial industry. The military uses mil-spec to ensure systems can withstand the harsh military operating environment. From an industrial standpoint contractors equate mil-spec to their commercial item description (CID) in establishing standards

for equipment. In the last five years, this topic has drawn significant attention in several professional journals.[12] The feature articles agree that environmental forces pose the greatest danger to computers. For example, David Schiff, a processor design engineer and Paul Wilson, a senior development engineer, discussed the issue of mil-spec from both a commercial and military perspective.[13] From the industrial standpoint, the environmental factors that influenced computer development primarily focused on withstanding the shock of shipment and the mild fluctuations in temperature associated in transportation. From the military perspective, specifically the Navy, fluctuations in power and operations in extreme temperature ranges appeared to be the most important factors. In essence, the degree of environmental influence was the difference between mil-spec and CID.

Over the years, improvements in circuitry design and technological advances have led to more sturdy and reliable desktop computers. In a 30-month field test of 40 desktop computers by the 10th Mountain Division, the computers were subjected to field operating conditions in Puerto Rico and Germany in temperatures ranging from -40 degrees fahrenheit to +100 degrees fahrenheit with only two minor failures.[14] This example illustrates that CID's in which commercial computers are built have come closer to mil-specs but have not yet and probably never will accommodate the stringent

requirements for military.

As the DOD saw the utility of using CID's over mil-spec, CID's were favored over mil-specs in designing systems. In the Secretary of Defense's (SECDEF) 1992 annual report to the President and Congress, he stated that,

> Over 35,000 military specifications and standards were reviewed with the intent of replacing as many as possible with commercial item descriptions. As a result, 2,500 have been canceled outright, 1,500 have been replaced with CID's or industry standards.[15]

As the military budget continues to decrease, DOD will place greater emphasis on using CID's in lieu of mil-specs. The military will eliminate much developmental testing providing that the vendors' testing methodology is acceptable. The result will be a reduction in overall R&D costs and time.

The Threat

A major consideration in determining the requirements of a weapons system is the threat. At the strategic level, documents signed by the President, Secretary of Defense and the Chairman, Joint Chiefs of Staff (JCS) indicate that

> The Soviet threat which once faced the United States has virtually diminished. In fact it is difficult to identify one threat; and conceivable that there are multiple threats because of the changes in international security throughout the world.[16]

The Chairman, JCS does attempt to be more specific and points out that, "North Korea, a weakened Iraq and a hostile Iran pose a threat and thus require US military forces to be maintained."[17]

The US Navy has reassessed its role in the military

and published a new policy in view of the on-going changes in the world. According to the Secretary of the Navy's White Paper,[18] mines, sea-skimming cruise missiles, and tactical ballistic missiles remain a formidable threat against the Navy's current systems and force structure. If this in fact is the case, then the Naval commander afloat must have the capability to rapidly evaluate a possible hostile threat that possesses the capability of launching a low altitude, high speed weapon with a small cross sectional radar image or a long range high altitude missile. In either case the Naval commander must react decisively to counter the threat.

Survivability

As important as mil-specs and mil-stds are in the technical design of C3I computer equipment, the end-users want equipment that is survivable in an operational environment. Professional writers present a broad range of opinions and comments on survivability.[19] Survivability can be viewed from two perspectives, a peacetime and wartime environment. Perhaps the most common and prevalent question is whether C3I equipment can survive in a worst case scenario, the effects of electromagnetic pulse (EMP) from a nuclear attack in a wartime environment. Major Melvin Hoke, an Air Force officer assigned as an electromagnetic compatibility engineer, discusses the use of NDI in a nuclear environment.[20] In a peacetime environment

survivability in terms of the operating environment include extreme temperature changes and power fluctuations.

Conclusion

The literature review has highlighted some of the significant areas that relate to the subproblems stated in chapter I, and in turn the primary thesis question. By analyzing the procurement process over the past two decades, the use of NDI technology over military specifications, and the test and evaluation process, I attempted to assess if the military has taken the appropriate and necessary steps to reduce costs and streamline weapons system acquisition by applying COTS over mil-spec items in developing new C2 systems with respect to meeting the operational requirements of the user. However, literature regarding system survivability in view of a nuclear threat was limited and the threat of computer viruses to software was not existent. Additionally, with the recent use of COTS equipment, the impact of the tradeoffs in system performance and maintenance have yet to be determined in terms of affecting a tactical commander's decision-making.

Endnotes

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CHAPTER THREE

METHODOLOGY

This research used two methodologies to answer the investigative questions pertaining to the research question. I used the historical method to answer the first subproblem and the case study approach to answer the second.

Subproblem Number 1

The first subproblem was to determine the differences in current DOD procurement policy in comparison to the previous one.

1. The data needed. The data needed for solving the first subproblem were national level documents, Secretary of Defense reports, DOD Directives, JCS publications, SECNAV instructions, and government studies pertaining to the acquisition policy for commercial off-the-shelf items.

2. The Location of the Data. The Combined Arms Research Library (CARL) contained all data with the exception of SECNAV instructions. SECNAV instructions were found in the Navy office in Bell Hall. All data was readily available.

3. Treatment of the data.

a. Analysis. I used these reports and documents were used to identify the changes and revisions in the procurement policy. First, I reviewed the administration's policies to look at why DOD conducted these studies. I only examined the period from 1970 to the present. Secondly, I reviewed the government studies conducted to identify what were their findings and recommendations regarding the acquisition policy. Next I reviewed the SECDEF reports to determine what actions DOD took to incorporate those recommendations into DOD Directives and Instructions to support improvements in the acquisition process. And finally, I reviewed the monographs, dissertations, and journal articles to determine any other findings used to support the use of COTS items in the procurement of C3I systems.

b. Interpretation. Analysis of the literature provided a chronology of how NDI procurement evolved, and what specific changes occurred, that led to the conclusion of whether the current procurement policy is better or worse than the previously existing one. This also provided a basis for answering subproblem number 2.

Subproblem Number 2

The second subproblem was to determine the operational suitability and operational effectiveness (i.e., reliability, availability, maintainability, etc.) of COTS

computer equipment to meet the Navy's requirements in a tactical environment.

1. The Data Needed. The data needed to resolve subproblem #3 were Operational Test and Evaluation (OT&E) Reports, Test and Evaluation Master Plans (TEMPs), government studies and articles that discussed the OT&E process.

2. The Location of the Data. The OT&E reports were located at COMOPTEVFOR, Norfolk, VA. Articles and writings pertinent to OT&E were found in periodicals located in CARL.

3. The Means of Obtaining the Data. The CARL through the Defense Technical Information Center system secured the required data.

4. Treatment of the Data.

a. Analysis. The technique I used was the case study research method to review the data and compare Navy operational test and evaluation reports for C3I systems procured under the past and present procurement policy. I then analyzed the results in terms of the operational effectiveness and suitability of the systems to support the tactical commander. Specifically, I:

(1) Reviewed and analyzed the history of TFCC and JOTS programs focusing on when notable events occurred that either contributed or detracted from the length of the procurement time and the associated costs.

(2) Reviewed journal articles, government

studies and DOD Directive 5000.3 Test and Evaluation governing the OT&E process. Then I reviewed the test procedures for FDDS and JOTS to determine if they conformed to the DOD Directive 5000.3 Test and Evaluation.

(3) Reviewed and compared the test results for operational effectiveness in the OT&E reports. The principle objective was to determine if the two systems supported the tactical commander and which one was better at providing him with the necessary intelligence to make informed decisions. I divided operational effectiveness of the C2 systems into elements that included afloat commander support, information exchange/processing, data base management, and correlation/matching. To ensure a fair evaluation I used the same scale to analyze functions common to both systems. When functions were available in one system but not the other, I evaluated them to determine whether they enhanced the commander's C2 capability.

(4) I reviewed the system test results for operational suitability to determine if the thresholds for reliability (MTBF), availability (A(o)) and maintainability satisfactorily met the old and new procurement policies. Additional suitability issues evaluated were survivability, logistic supportability, compatibility, interoperability, training, human factors, safety, documentation, and vulnerability.

b. Interpretation. In the comparison of the data I attempted to explain how one C3I system procured under one policy was better than the other procured under the other policy. The criteria I used was whether it met the operational requirements of the tactical commander. Additionally, I explained how one policy was better than the other in terms of streamlining the acquisition cycle and reducing associated costs.

CHAPTER FOUR

ANALYSIS

Command and control (C2) systems acquisition is one of the most complex challenges in military weapon system procurement. C2 acquisition is inherently more difficult in that the requirements are less definitive and more conceptual than that of a weapons system, which is designed with a specific requirement to destroy a target. The lack of threat specificity coupled with rapid advances in computer technology has made C2 acquisition even more complex. To adhere to the DOD acquisition policy was difficult. The research conducted to answer the thesis question first analyzed the procurement process and then compared the operational testing and evaluation results of two C2 systems procured under different policies.

Subproblem Number 1

The first subproblem was to determine the differences in the Department of Defense's (DOD) current acquisition policy and the old one. To answer the question, I analyzed acquisition and procurement of military weapons systems from 1970 to the present. I looked at DOD policy covering weapons systems acquisition in general and then focused in

on two Navy C2 systems. Within the context of C2 systems, I discussed how the Navy handled the challenges of procurement of these C2 systems. To adequately address the first subproblem, the thesis analyzed government studies, technological advances that affected acquisition strategy, the goal for achieving greater efficiency, the impact of budget reductions and the nature of the threat during the period the system was under acquisition.

History

Fitzhugh Commission

For decades, the DOD has had the luxury of operating relatively independent with little intervention by outside organizations or agencies in regard to how business should be conducted or run. In July 1969, President Nixon and Secretary of Defense (SECDEF) Melvin Laird gave the Fitzhugh Commission (President's Blue Ribbon Defense Panel) the task of conducting an indepth study, of the Department of Defense's (DOD) organization and management practices and making recommendations.

After a year long study and examining procurement policies and procedures the Fitzhugh Commission reported to the President in July 1970 that,

> The acquisition of weapons systems and other hardware had contributed to serious cost overruns, scheduled slippages and performance deficiencies. Furthermore, the panel observed that the difficulties did not appear amenable to a few simple cure-alls, but required many interrelated changes in organization and procedures.[1]

The commission identified two key areas requiring change. First, the panel found that deficiencies in the operational testing and evaluation (OT&E) process was infrequent, poorly designed, and generally inadequate in measuring the effectiveness of weapons systems prior to fielding.[2] It recommended that a Defense Test Agency be established under the supervision of a civilian director directly responsible to SECDEF to manage DOD testing and evaluation. Under the policy then, in effect, the services conducted their own testing and evaluation and reported to their respective service chiefs. No one individual, either military or civilian, maintained oversight of the OT&E process.

Secondly the Fitzhugh Commission identified deficiencies in research and development. Specifically, unproven technological advances produced risks and uncertainty in the development of systems. This resulted in cost growths, delays in the program, and shortfalls in desired performance of the system.

> In March 1971, DOD-selected procurement reports of 45 systems amounted to $110 billion and accounted for cost overgrowth in the following categories: technical changes, 20%; delivery schedule changes, 17%; abnormal economic fluctuations, 18%; incorrect estimates, 29%; and other causes, 16%.[3]

The Fitzhugh Commission also found that, "Cost overruns were not new but in the 1960's and 1970's, they attracted public awareness to an extent uncharacteristic of previous times."[4] Subsequently the American public demanded increased

accountability for the military to ensure tax dollars were being spent wisely.

The commission also found that management deficiencies were a substantial contributor to the acquisition problems. For example, one of the problems was Robert McNamara's failure to reorganize the DOD to emulate a large private corporation and achieve success in the 1960's.[5] Another major problem noted was that frequent officer rotations did not allow the officers the time to gain the necessary experience to perform adequately at their jobs until near the completion of their tours.[6] In a technical area, such as acquisition, the officer's job assignment needed to be of sufficient duration so that he could become thoroughly involved in the work and be fully responsible for the results.[7]

The Fitzhugh Commission recommended that DOD establish career paths for officers assigned to staff, technical, and professional fields in such areas as research, development, and procurement. Further, the commission recommended that the duration of those assignments be increased and that officers' opportunities for promotion should not be hindered due to increased tour lengths in those specialty fields.[8]

DOD received the Fitzhugh Commission's recommendations and incorporated several of the recommendations to include extended tour lengths, specialist

career pathing, and establishment of an additional DOD staff position. In SECDEF Laird's statement before the Senate Armed Services Committee in February 1972, he announced the appointment of a Deputy Director for Test and Evaluation to improve the quality of testing.[9] SECDEF Laird felt this would resolve the OT&E issue.

In the area of systems acquisition management, SECDEF Laird relayed three key points that his Deputy, Dave Packard observed during his tenure. First, wrong decisions were made to start new but unrealistic programs. "Many programs had problems because they were poorly defined from the beginning. Frequently more performance was requested than was really needed in a new weapon."[10] To correct this deficiency the administration provided specific guidance that supported national security objectives in procurement of new systems. Additionally, procurement officials began to place greater emphasis on the views of the Joint Chiefs of Staff and the requirements of the Unified Commanders in Chief. Subsequently fewer projects were cancelled. However, almost a decade elapsed before the CINC's became intimately involved in the planning of C3I requirements and future needs.[11]

Second, Deputy SECDEF Packard observed that DOD officials accepted cost estimates even when they were unrealistic. SECDEF Laird pointed out that over-optimism in evaluation of the technological difficulties involved in

achieving desired performance compounded the problem as well as the under-estimating of the time and costs. These accepted practices contributed to the problem.[12]

Third, DOD management provided ineffective oversight in procurement. The Fitzhugh Commission recommended the establishment of five new assistant Secretaries of Defense for improving DOD management and organization. However, SECDEF Laird opposed the recommendation and argued that he would support two new positions, instead of five, to avoid increased staffing. He believed this was one of the inherent problems to the already complex bureaucracy within the DOD.

At the middle management level, SECDEF Laird's solution for improving management was to select more capable project managers and to increase effectiveness by keeping them on the job longer. He also implemented changes to the Defense Weapons Systems Management Center, a school that provided officers entering the acquisition field the fundamentals for becoming program managers. Those changes would ensure that managers received the necessary training to perform their jobs properly.[13]

Although DOD established standards in its directives and instructions, the services did not adhere to them when procuring new systems. At one end of the spectrum, development consisted of paper studies rather than attempting to build a working prototype which employed

highly advanced technologies. The result was the expenditure of funds for a project that never left the drawing board. At the other extreme, full production began before completion of the system research.[14]

SECDEF Laird's solution to solving the problem of overlapping production schedules with those systems nearing completion in development was strict adherence to milestones. Milestones were stages in a program's acquisition cycle which are met before continuing on to the next phase of development. To achieve a specific milestone a system under procurement had to complete a phase of developmental testing and operational testing and have the required documentation before continuing on to the next phase. Additionally, the SECDEF encouraged the use of a less structured approach in the procurement process. Program managers now had some flexibility in "structuring development contracts to provide for tradeoffs between performance, time schedules, and costs throughout the development of the program until the weapon was approved for production."[15]

Using the Fitzhugh Commission's report as an impetus for encouraging changes to improve the DOD's acquisition process, SECDEF James Schlesinger reported to Congress in March 1974 his outlook towards future procurement for fiscal years 1975-1979. His approach was twofold. First, he emphasized the need to gain better control of the current

systems under procurement to preclude further recurrences of the same problems identified by the Fitzhugh Commission. Second, he was going to take a more sensible approach to buying new systems so that future systems would be more cost-effective and provide an acceptable level of performance at an affordable price.[16]

To gain greater control of those systems under procurement, SECDEF Schlesinger implemented two management policies.[17] For those programs at the design stage, he promoted greater use of prototyping. Prototyping was a low cost investment to determine if a concept was actually worth pursuing before the commitment of significant funds. For those programs at the developmental stage, he mandated initial OT&E before production could begin. This effort reduced the need for costly modification and increased the probability of avoiding failures before actual production. Also, by establishing a Deputy Secretary of Defense for Research and Engineering for Test and Evaluation, he ensured enforcement of his "Fly before Buy" program was enforced.

For the procurement of future systems based on emerging operational requirements (OR), SECDEF Schlesinger implemented a new concept of "Design-to-a-Cost" program in fulfilling an OR as economically as possible.[18] His "Design-to-a-Cost" concept hinged on the services producing accurate cost estimates for new systems. Concurrent to the services calculating cost estimates, a Cost Analysis

Improvement Group within the Office of the Secretary of Defense (OSD) developed its own impartial cost analysis of the service's proposed system. Then, a cost comparison was made to determine the reasonableness of the system. Finally, performance characteristics that would satisfy the OR and a time schedule were developed to fit the estimated cost. This concept also allowed program managers to adjust the performance characteristics and time schedules as necessary to remain in line with costs.

SECDEF Schlesinger's new approach to weapons systems procurement also fostered the use of commercial standards, where practical, in lieu of military specifications (mil-specs) and promoted the use of "off-the-shelf" components. By encouraging such tradeoffs, he allowed maximum flexibility in how a system was to be built which realized savings in life-cycle costs.[19] This issue would resurface later in the Grace and Packard Commissions' studies conducted in 1982 and 1986. Subsequently, the DOD made this procurement method official policy, and it became the norm for all services.

Defense Science Board (1977)

In December 1977, the Under Secretary, Defense Research and Engineering, William J. Perry established the Defense Science Board (DSB) Task Force to study C2 systems management and make recommendations for improvement.[20] The DSB, chaired by Dr. Solomon Buchsbaum examined five areas in

command and control. Three areas pertained to joint and multi-service issues which included the procurement of systems for joint and multi-service use; the effectiveness of C2 procedures in a joint environment such close air support and battlefield interdiction; and the relationship between the joint interoperability council and World Wide Military Command and Control System council. The last two areas were within the scope of this thesis. The first area examined the existing procedures and directives regulating weapons systems procurement and their applicability to C3I systems; and, second, the existing management organization handling C3I systems and whether or not changes were necessary. If changes were needed, "the task force was urged to develop recommendations that if implemented, would help improve the design, acquisition, operation, and evolution of command and control systems."[21]

The DSB, in its 10 month study discovered many flaws in the existing program structure. The number one concern was that existing C2 systems were not commensurate in technology when compared to the modern weapons systems of destruction. In the past the services placed emphasis on developing destructive weapons systems which enabled the United States to maintain the edge over the Soviet Union, and consequently, C2 systems development received a much lower priority.

Second, the DSB found that C2 systems, unlike weapons

of destruction, were very complex in design and had unique characteristics.[22] Development was primarily evolutionary rather than developmental in nature. As new advances in technology appeared, they became part of existing systems. The primary emphasis of this effort was incremental upgrades in software that enabled increased performance. By the time a single system entered the field, its characteristics were very much different from what the original design called for. This uniqueness ensured C2 systems did not follow the standard acquisition path.

The DSB concluded that DOD Directive 5000.1, Major Systems Acquisition, was not applicable to the procurement of C2 systems. The DSB strongly recommended an addendum that would provide the necessary guidance to program managers for C2 systems acquisition. The DSB also proposed the establishment of a new agency, designated as the Defense Command and Control Systems Support Agency, to:

> Assist the Unified and Specified Commands and the JCS in the development of command and control system requirements and specifications; to establish technical standards for interfacing specifications; to perform development planning including alternative concept trade-off studies; to develop master plans for programming and budgeting of various C2 developments and procurement.[23]

The DSB also produced a draft addendum (DOD Directive 5105.XX) to establish guidelines for what the Defense C2 Systems Support Agency was supposed to do.[24] The Under Secretary urged the SECDEF to implement the board's recommendations to correct those deficiencies. However, DOD

never incorporated the draft addendum as a supplementary directive to DOD 5000.1. Instead, the DOD published it as a Defense Acquisition Circular, which did not have the same impact as a DOD Directive.[25]

DOD Directive 5000.1 series was revised and updated in 1977 and 1980. In March 1982, Deputy SECDEF Frank Carlucci made the first significant revision, based on the Acquisition Improvement Program to streamline the acquisition process.[26] The major change in the directive was the reduction of the five milestone decision points to three, thereby taking years off the lifecycle of a program.

Grace Commission

Defense spending was a priority in the 1970's in light of the national debt, but as the national debt continued to climb it became an even higher priority. "On June 30, 1982, President Reagan signed Executive Order 12369 and established the President's Private Sector Survey on Cost Control."[27] The 45 member task force committee known as the Grace Commission included chairmen and presidents of leading corporations throughout industry. The commission's objectives focused on studying DOD management practices on weapons procurement, logistics, financial management, personnel, legal, and legislative issues. The commission's task was to make recommendations to increase efficiency and determine ways for achieving cost savings. The commission's mandate was to:

> Identify opportunities for increased efficiency and reduced costs achievable by executive action or legislation, and specify areas where further study can be justified by potential savings.[28]

The Grace commission found two areas that required reform. First, the commission found that OSD and the four branches of service were duplicating their efforts in procurement management. The OSD through the Under Secretary of Defense for Research and Engineering provided guidance, policies, and procedures on acquisition of weapons systems in accordance with the DOD Directive 5000.1 and DOD Instruction 5000.2 (applicable to all services).[29] Each branch of the services had a similar organizational structure in which program managers reported to their respective service secretary and then the service secretaries reported to the OSD.[30] As identified later by the Packard Commission, a key to success was establishing the shortest lines of communications possible to promote efficiency and get the job done.[31]

The commission reported that "DOD should initiate a program to modernize and streamline the total acquisition process by consolidating the entire process into OSD."[32] As a start, it recommended that "DOD should seek legislation to establish the position of Under SECDEF for Acquisition within OSD."[33] The Under SECDEF would then have the authority and responsibility to develop and implement a program to restructure the procurement system.

The second major issue identified by the Grace

commission was the lack of use of common parts and standards. The commission found that each service carried out procurement independently and in areas where similar weapons systems were under acquisition, they duplicated efforts. The commission recommended that,

> DOD should mandate the use, where possible, by all services of common hardware components, subsystems, equipment and other parts in order to minimize acquisition and life-cycle costs. The potential savings would equate to approximately $2.3 billion annually.[34]

In attempting to reduce the costs of components, the commission closely scrutinized the use of mil-specs. They discovered that the application of mil-specs was often over used.[35]

The commission found that "procurement officials were not sufficiently selective in choosing only the particular military specifications that were truly needed in relation to the end item being procured."[36] Program manager often wrote poor requests for proposals. Industry officials believed that program managers concentrated heavily on determining what specifications to select rather than the requirements of the system.[37] As a result, the extensive time and effort devoted to developmental testing of components to ensure they met the standards specified in the contract often drove up costs.

Packard Commission

In July 1985, President Reagan tasked his Blue Ribbon Commission on Defense Management (Packard Commission) to conduct an indepth study on defense management and organization and report its findings and recommendations.[38] Compared to previous studies this was the most comprehensive and indepth study of the problem. It covered the full spectrum of the DOD, but within the scope of this thesis, the author only addressed the procurement process.

The Packard Commission's study of the procurement process revealed many of the same findings observed in previous government studies.[39] In analyzing top level management, the commission observed that, "There is today no single senior official in OSD working full-time to provide overall supervision of the acquisition system."[40] The establishment of a deputy director in research and engineering, and test and evaluation by former SECDEFs Laird and Schlesinger were not sufficient to resolve the overall problem. The services took on the responsibility themselves to exercise authority of DOD policy within their branch. Unfortunately, each service acted in their own interests and in the long run uniformity in following procurement policy deteriorated due to lack of centralized control.

Twelve years after SECDEF Schlesinger reported to Congress and promoted the use of prototyping, the Packard Commission re-emphasized the need for prototyping. The

commission observed that prototyping did not gain enough support in the past and that it should receive much higher priority. By doing so, the commission believed that a service could satisfactorily conduct a proof of concept demonstration using the latest technology available to determine if a new system in fact actually worked. If it did work, the prototype system would provide a basis for realistic cost estimates before entering full production.[41]

In the area of parts, components, and subsystems, the commission observed the reliance on excessively rigid military specifications.[42] The Packard commission observed that no matter how efficient DOD became, it could not take advantage of economies of scale and manufacture parts as cheaply as the commercial marketplace. The products developed to military specifications for exclusive military use generally cost substantially more than commercial counterparts. As an example, the commission determined that the unit cost of a militarized computer microchip was 3-10 times that of its commercial counterpart.[43] As a result the commission recommended that only when readily available items did not meet military requirements should new or custom-made items be considered.

The commission did not disregard the fact that military computers needed to be rugged in order to withstand the rigors in the operational environment; but it also noted that industry standards for producing microchips had been

greatly improved over the years.[44]

President Reagan approved the Packard Commission's recommendations and signed National Security Decision Directive 219 on 1 April 1986 placing them into effect.[45] DOD followed suit and revised its DOD directives and instructions accordingly. The Navy implemented the Packard commission's recommendation for promoting the use of NDI in Secretary of the Navy Instruction (SECNAVINST) 4210.7, specifically stating that:

> It is Secretary of the Navy policy to institutionalize NDI consideration during the acquisition process to an extent that its use becomes the rule rather than the exception.[46]

Defense Science Board (1986)

The momentum for improving DOD's procurement policy continued, and in September 1986 the Under Secretary of Defense for Research and Engineering Donald Hicks tasked the DSB to review progress regarding the recommendations made since the last DSB study conducted in 1978.[47] The DSB consisted primarily of the same board members, and they reported that significant progress had been made in the past eight years. The key to the success of bringing C3I systems into the realm of current technology was the CINC's involvement. Since 1982, DOD required each CINC to submit an annual Command and Control Master Plan containing requirements and future plans.[48] By involving the CINC's in the planning, it gave planners a better framework for

developing the next generation of C3I systems.

As the years passed, remaining DOD directives were revised to reflect President Reagan's signing of National Security Decision Directive 219. Specifically, DOD Directive 4120.20, Development and Use of Non-Government Standards was revised in March 1988 which directed acquisition personnel to use nongovernment standards when designing an item unless otherwise specified by law, multinational treaty, or its use was not economically feasible.[49]

As an example, the next subproblem examined how the Navy adapted to the changes in DOD procurement policy during the period from 1970 to 1990. Additionally, the next subproblem illustrated two C3I systems procured under different policies.

Subproblem Number 2

The second subproblem was to determine the operational effectiveness and suitability of COTS computer equipment in meeting the naval commander's operational requirements in a tactical environment. To answer the second subproblem, I compared and analyzed two C2 systems, the Tactical Flag Command Center Increment II and Joint Operational Tactical System I.

The second hypothesis was that COTS computer equipment employed in a tactical environment to support the

Naval Commander meets his operational requirements but does not meet the military standards promulgated under the new procurement policy.

To familiarize the reader with the two systems that this study compared and analyzed, I have provided a brief mission and system description of each.

Background

History

Tactical Flag Command Center (TFCC). The TFCC program began in 1971 as a research and development program for concept development and validation of an automated processing system for intelligence information. The program began as Multi-Source Processing System (MSPS) and assumed different project names over the course of its development (Table I). COMOPTEVFOR conducted operational testing and evaluation of MSPS in 1974 and validated the concept. COMOPTEVFOR also concluded that the system had the potential for supporting the tactical commander at sea and recommended further development be conducted. The Navy approved the recommendation for further development in December 1974.[50]

In early 1975, COMOPTEVFOR conducted additional OT&E of MSPS, then called OUTLAW SHARK and identified areas requiring refinement to improve the system. Again, COMOPTEVFOR concluded that the system had significant potential for supporting the commander afloat with processed intelligence information. In June 1975 the Navy established

the OUTLAW SHARK program as a formal C2 program and renamed it TFCC. From June 1976 to July 1977, COMOPTEVFOR conducted additional OT&E of TFCC, and they observed deficiencies that were should have been identified during developmental testing.[51] For example, the developing agency did not verify system hardware and software readiness, standard operating procedures and manning requirements.[52]

In the Fall of 1977 the Chief of Naval Operations (CNO) suspended further development, pending review and restructuring of the Navy Command and Control System program. Over the next two years, program managers finally developed a firm plan that received CNO approval, and the Navy reactivated the TFCC program in August 1979.[53]

The TFCC program was restructured and divided into three incremental phases. TFCC Increment I was a space upgrade in aircraft carriers (CV/CVNs). This phase provided the embarked tactical commander with existing Navy equipment that included vertical status boards, Naval Tactical Data System (NTDS) consoles, and communications capabilities to support his decision making. TFCC Increment II incorporated the Flag Data Display System (FDDS), an updated version of OUTLAW SHARK. FDDS performed automated information processing and display and also provided for the manipulation and display of tactical information. The Navy installed the system onboard six aircraft carriers. TFCC Increment III provided for evolutionary improvements which

were not yet defined.

Over the next several years the Navy conducted additional phases of DT and OT (Figure 1) that refined system performance prior to OPEVAL.

Joint Operational Tactical System I (JOTS I). JOTS I began as a fleet initiative under the sponsorship of the Commander in Chief, Atlantic Fleet (CINCLANTFLT), funded under a rapid prototype program that was developed to satisfy Operational Requirement 249-094-89 in August 1989.[54] The requirement was for a downsized desktop computer-based tactical system to provide information transfer, display and decision aids for afloat users. The fleet CINCs used JOTS I to address deficiencies in processing wide area surveillance information, and to provide tactical decision aids (TDAs) not being met by other afloat C2 systems.

Of the eight remaining aircraft carriers that did not have FDDS installed, JOTS I served as the interim C2 system in TFCC for the embarked tactical commander.

Mission Description

TFCC Increment II. TFCC Increment II or FDDS were synonymous terms. This study treated these as one and used the acronym FDDS. The FDDS was an automated data processing system designed to process and correlate surveillance information from external sources received via various modes of communications (i.e., satellite, radio) as well as

organic sources within the carrier battle group. The system performed data base management functions and contact correlation, and it displayed the alphanumeric and graphic information on a large screen display (LSD) for use by the embarked tactical commander. As a final note, the system was not designed to counter any specific threat as stated in its operational requirement.[55]

JOTS I. The JOTS I system processed surveillance information, transferred tactical information to other C2 systems, such as Tomahawk Weapons Control System (TWCS), and provided TDA's in support of the tactical commander. JOTS I provided the capability to receive data via various modes of communications (i.e., satellite, radio) for processing; to interface directly with other C2 systems (i.e., FDDS, TWCS, Prototype Ocean Surveillance Terminal (POST)); and to perform contact association/matching and data base management. JOTS I also generated and exchanged color tactical graphic displays; and provided Point of Intended Movement capability, satellite vulnerability capability, and TDA's for supporting subordinate warfare commanders. JOTS I was not designed to counter any specific threat as stated in its operational requirement.[56]

System Description

FDDS. The FDDS (AN/USQ-81(V)) system consisted of the following:[57]

1. AN/UYK-19 computer (64k bites of memory)

2. Associated peripherals

3. Operator Interface Terminals (OITs) networked in TFCC, Carrier Intelligence Center (CVIC), Combat Direction Center (CDC), and Supplementary Plot (SUPPLOT)

4. Disk memory (2Mb)

5. Magnetic Tape Recorder

6. Hard copy Plotter

7. Sanitization Terminal

<u>JOTS I</u>. The JOTS I system consisted of the following:[58]

1. Five HP-9020A/C desktop computers, each with a built-in monitor and keyboard

2. Rocky Mountain BASIC operating system written in BASIC language

3. Hard drive (either 55Mb or 120Mb)

4. Typically configured as a five terminal system connected via a local area network in TFCC, CVIC, CDC, and SUPPLOT. The JOTS master terminal was located in the TFCC and functioned as the network server.

5. Hardcopy printer/plotter

6. The system also included peripherals such as a large screen display, remote monitors and remote control devices (digipads) for manipulating the displays.

TFCC Acquisition Cycle

The TFCC program as depicted in Table I and Figure 1 and as described in the historical background section has had a long acquisition cycle that from the time of its inception spanned almost 17 years. In the program's earlier years, COMOPTEVFOR observed that TFCC lacked direction when it conducted its operational assessments. It was a program that was a first of its kind, and it experienced growing pains, most notably in 1977 when CNO suspended it.

In looking at the progression of the TFCC program, TFCC was a good example of what the DSB had stated about the uniqueness of C3I systems acquisition. It was complex and evolutionary in nature as well as software intensive.

When the TFCC program regained its stature in mid-1979, the Navy approved two engineering development models (EDM's) for production. The first system reached initial operating capability (IOC) in mid-1983 and was installed aboard the aircraft carrier USS AMERICA.[59] The program was now on track, and it adhered closely to the DOD Directive 5000.3 Test and Evaluation for conducting OT early on following the completion of DT (Figure 1 and Table I). With the exception of one test phase in September 1981, both OT and DT were combined due to limited availability of resources.

Figure 1 also depicted the associated costs accumulated over the program's lifecycle. Beginning with

program reactivation in 1979, the initial R&D costs were over $50 million and continued to increase incrementally over the years, taking into account inflation. By the end of FY89, the total RDT&E costs had reached $149,043,000; procurement costs for six FDDS systems, $102,839,000; ship's new construction, $74,741,000; and operations and maintenance, $56,876,000.[60]

JOTS Acquisition Cycle

The JOTS acquisition cycle was unlike any C3I program under procurement. The system received its beginnings in 1982 under the direction of then RADM Tuttle, Commander Carrier Group Two. JOTS was a low cost system that provided Navy management functions hosted on a commercial HP9020 desktop computer. The costs were so slight that it was supported solely by Operational and Maintenance Navy funds, funds that paid for fuel and parts. The capability of the JOTS system grew in the ensuing years and gained widespread support from the fleet. For a small investment of approximately $55,000 in ship's OPTAR, commanding officers had the capability to fill a void in their C2 and also conduct operational planning.

In essence, the fleet supported the program as opposed to a sponsor in Washington, DC. The proliferation of JOTS systems was not a problem, until maintenance was required. Unfortunately, logistic support for the system did not exist within the Navy supply system and the vendor

provided maintenance.

Eventually, the JOTS program was given a sponsor who would oversee the program and who had the authority to develop a support structure to include necessary documentation and logistic support. Figure 2 depicted the associated costs accumulated over the program's lifecycle. Because JOTS was a fleet initiative, R&D costs were zero for the first 7 years and only began to accumulate slightly when a program sponsor was identified and took charge in FY 89. Procurement costs for 219 JOTS systems acquired by fleet units were approximately $2,200,000; and operations and maintenance costs, $500.000 (Figure 2).

OT&E Process

OT&E adhered closely to DOD policy and followed the guidance of conducting OT 30 days after the completion of DT. FDDS and JOTS I operational assessments were conducted following the completion of DT (Table I and II). Hillman Dickinson, Director of C3 systems, JCS, discussed the difficulty in performing realistic evaluation of C3 systems, but lauded the Navy's efforts in this area.[61]

In determining whether sufficient testing was conducted prior to OPEVAL, it did not appear to have been the case for FDDS or JOTS I. If sufficient DT and OT were conducted to resolve deficiencies and make corrections, the results of OPEVAL (Table IV) would have indicated higher satisfactory grades than those actually acquired.

The Test Environment

The FDDS and JOTS test environments were operationally realistic, but limited in scope in that they did not duplicate operations in a worst case scenario. The operational testing for FDDS was conducted in a non-combat environment in the North Arabian Sea for a period of 14 days aboard USS AMERICA (CV 66) and supported the carrier group commander, his staff, and USS AMERICA's operations department. Testing was of sufficient length in time to evaluate all but one test objective, maintainability.

The operational testing for JOTS was performed in conjunction with a fleet training exercise off the Atlantic coast under simulated wartime conditions. JOTS was installed aboard USS FORRESTAL (CV 59) and supported the Carrier Group SIX commander.[62] As discussed in subproblem number one regarding the validity of the operational testing and evaluation of systems under procurement, I observed that both FDDS and JOTS both adhered to the guidelines and procedures for testing in DOD Directive 5000.3, Test and Evaluation.[63]

The test environment did not include the effects of EMP on the system. However, other sources of information that discuss the effects of EMP in a nuclear war were classified and beyond the scope of this thesis.

Operational evaluation (OPEVAL), the phase of

operational testing that provides results and conclusions that determine if a system under procurement will go into full production was used as the basis for conducting the comparison and analysis of FDDS and JOTS. Prior to OPEVAL, a system will have all deficiencies identified in the laboratory environment corrected or resolved and receive certification from the program manager that the system is ready for OPEVAL.

Operational effectiveness

The principle test objective was to evaluate the overall effectiveness of each system to provide timely and accurate data to support the afloat commander and to determine which one was better. Details in system performance were subdivided and evaluated by function and summarized in Table III. The specific functions were graded SAT, UNSAT, and UNRESOLVED based on COMOPTEVFOR's observations and analysis. Functions that were unique to one system which did not lend themselves to comparison were evaluated for their value-added potential/capability to support the tactical commander. In areas where functions were the same or similar but identified by different terminology, annotations were made in Table III notes for clarification.

COMOPTEVFOR observed that FDDS and JOTS did not adequately demonstrate the capability to support the afloat commander overall.[64] FDDS received UNSAT grades in all

areas of operational effectiveness with the exception of two. Those two areas were part of JOTS evaluation (security and TDA's) and not applicable to FDDS. TFCC, CDC, CVIC, and SUPPLOT were certified as secure spaces in which to house classified materials and equipment during aircraft carrier construction and therefore not identified as an issue in the TEMP. TDA's were not yet developed into the FDDS software and therefore were not evaluated. JOTS I received 5 of 7 UNSAT marks in operational effectiveness. Operational effectiveness issues were evaluated by how effectively information was handled by function. Details were provided in the following paragraphs.

One of the primary functions of a C2 system was to determine how effectively information was processed and exchanged over the communication circuits. COMOPTEVFOR observed that FDDS and JOTS I were both inadequate in performing this function. FDDS was not sufficiently automated to handle the volume of duplicate messages received over the multiple communication circuits. (Multiple communication circuits provided a redundant as well as alternate means of receiving messages in the event of communications problems.) COMOPTEVFOR observed that information was backlogged for processing and required extensive operator intervention to alleviate the buildup. In the instances of duplicate messages, FDDS reprocessed the information several times as opposed to recognizing the

duplicate and discarding it.[65]

JOTS I possessed the capacity to store a greater volume of incoming messages in buffers but failed to adequately process all messages.[66] The percentage of unprocessed messages was small but statistically significant enough to make a difference in the accuracy of the tactical picture (the classification of the data precluded disclosure). The most important messages that were not processed were contact reports (positional reports of friendly, enemy, or neutral surface, subsurface, or air contacts) that contributed to the development of an accurate tactical picture. The inadequacy of this JOTS I function led to a degraded tactical picture and affected the Force Over-the-Horizon Track Coordinator's and Anti-surface Warfare Commander's abilities to effectively fulfill their mission requirements.[67]

To compound the information processing problem, FDDS and JOTS I did not adequately correlate the incoming contact reports correctly. The correlation and matching was primarily an FDDS and JOTS I function; however, operator intervention was required in many cases. The correlation process involved the use of contact attributes (i.e., unique information, such as ship name, hull number, international call sign, ship class, geographic position) in performing the calculation. In the FDDS system, a scoring system was used by assigning values (0-100) to attributes. The

numerical value assigned was based on the uniqueness of the attribute. Unfortunately, the algorithm was simplistic and operator intervention was required in resolving 52 percent of the ambiguous reports.[68]

JOTS I experienced a similar problem. Its correlation algorithm was even more simplistic than FDDS. All attributes were not weighted; and instead, JOTS I compared the attribute information between contacts and conducted a geo-feasibility analysis to determine the likelihood that a new contact was in fact an updated one. Geo-feasibility analysis was a calculation based on time, distance and position of two possible candidates within proximity of one another as being the same one. The calculation determined the likelihood that a contact (air, surface, or subsurface) could be the same based upon the difference in time, distance and speed.

Once incoming message reports were processed (correlated if they happen to have been contact reports), the data was stored in various data bases depending on the type of message. The FDDS system was inadequate in data base management. The procedures for the manual input and manipulation of data were time-consuming and labor intensive without regard to man-machine interface considerations.

JOTS I performed data base management functions satisfactory. The hardware capacity enabled the system to store additional types of data that included oceanographic,

weather, overlay, and satellite vulnerability data. No deficiencies were observed in the automatic posting and updating of such information.[69]

A key element in supporting the tactical commander's decision making process was to evaluate how effectively data was assimilated and comprehendible by means of tactical displays. Once information was stored, presenting the data in an the most effective manner to enable the tactical commander to quickly assimilate it and make a decision. The most effective means was through visual display. By having a clear, concise graphic display of how enemy, friendly, and neutral forces were arrayed, the tactical commander could then make an informed decision given the intelligence available.

FDDS failed to display a tactical picture effectively. The alphanumeric data cluttered the graphic displays and degraded the tactical picture, making the display unreadable.[70] Additionally, the tactical displays were static and presented only a "snapshot" view of the tactical situation. JOTS I provided a color display of friendly, enemy, and neutral contacts in near-real time and COMOPTEVFOR observed that no deficiencies were observed.[71]

Unique to JOTS was the availability of TDA's to enhance the tactical commander's decision-making. TDA's varied from simple range and bearing functions to more complex calculations, such as determining satellite

vulnerability periods (time frames in which military forces were subject to exploitation by non-US satellites). These aids were automated functions that gave him a significant advantage over manual methods of calculation and were readily available on the computer. Also, TDA's gave commanders the flexibility to perform "what if" calculations quickly and then modify operational plans as necessary.

Security was not a test objective during FDDS testing and was not evaluated. However, security was a test objective in JOTS testing, and testing revealed that adequate security measures did not exist to preclude unauthorized personnel or JOTS operators from accessing and altering the source code of the software. The impact would have been severely disrupted operations.[72]

Operational suitability

Operational suitability was described as the degree in which a system could be placed satisfactorily in the field with consideration given to factors such as operational availability, maintainability, reliability, logistic supportability, survivability, training, interoperability, safety, human factors, and compatibility.[73] FDDS and JOTS I were tested in all areas of suitability except survivability in a nuclear environment.

Both FDDS and JOTS demonstrated satisfactory performance in system reliability (Tables III). During the

OPEVAL, FDDS demonstrated an MTBF of 322 hours (criterion 72 hours), exceeding the criterion by 4.47 times. Although FDDS operated for only 322 hours (criterion 720) without a critical failure in hardware, COMOPTEVFOR observers subjectively evaluated the system's MTBMCF as satisfactory. As for MTBMCF (SW), FDDS halted seven times in 322 hours (criterion 4 hours), exceeding the criterion by 11.5 times. JOTS operated at least 876 hours without any hardware failures (criterion 500 hours and 250 hours for MTBMCF (HW) and MTBF (HW), respectively). Eight software faults were observed but JOTS I still exceeded the criterion by 7.26 times.

Maintainability for FDDS was unresolved because one repair job did not represent a statistically significant sample size for MTTR. JOTS received a satisfactory grade. Not discussed in the OPEVAL report was the importance of availability in spare parts which determined how long it took to repair a discrepancy. This variable was directly related to logistic supportability of the system and given the lack of spare parts, the operational effectiveness of the system could severely be degraded. Further details were discussed under logistic supportability. The mean time to restore-operator (MTTR-O) was 22.6 minutes (criterion 4 min). FDDS failed to achieve this threshold by a factor of 5.6 times.

The MTTR for JOTS I was not demonstrated because no

mission critical failures were observed. COMOPTEVFOR subjectively evaluated this objective as satisfactory, based on its observations. For MTTR-O, JOTS demonstrated an MTTR-O of 15 minutes, exceeding the criterion by a factor of four times.

In comparing the availability of both systems, FDDS received a performance evaluation of UNSAT whereas JOTS received a SAT (Tables IV). FDDS demonstrated an A(o) of .96, based on 310.2 hours of uptime out of 322 hours.[74] JOTS demonstrated an A(o) of .99, based on 874 hours of uptime out of 876 hours. The two hours of downtime were the result of software faults attributed to information overload.[75]

In the area of logistic supportability, FDDS was evaluated as SAT and JOTS, UNSAT (Table IV). The FDDS OPEVAL report stated, "No deficiencies were noted in spare parts required to support TFCC/FDDS and associated hardware."[76] Given the long procurement time of the system, the Navy supply system was able to establish an adequate integrated logistic support structure to provide for the system.

On the other hand, JOTS did not have an integrated logistic support program.[77] A maintenance program was not yet in existence, and spare parts and consumable items were not adequately stocked in the Navy supply system. Instead, logistic support was provided by the contractor. In <u>Buying</u>

NDI, one of the problems discussed in using NDI (i.e., COTS) was that the lead times for establishing an infrastructure to provide the necessary logistic support could exceed the time expended in fielding the system.[78] This was certainly true of JOTS. Additionally, the risks must have been acceptable, or the program manager would not have considered it as an option.

In the area of training, both FDDS and JOTS programs were inadequate in providing the necessary training to users in operating the systems with proficiency. The FDDS training program did not fully cover proper data base management, trouble-shooting procedures for the system, and team training which integrated officers and enlisted personnel.[79] For JOTS I, a formal Chief of Naval Education Training program had not yet been established. Training was ad hoc and provided by fleet mobile training teams and contractors.[80]

Compatibility of the systems operating within the established environment differed between FDDS and JOTS I. The FDDS system was compatible with the physical, electrical, and electronic operating environment.[81] JOTS I was not physically compatible within the operating environment. The system was installed on a space available basis and interfered in the maintenance of adjacent equipment within the same compartment.[82]

In comparing the technical documentation for

maintaining FDDS and JOTS, both were inadequate in providing logical and complete troubleshooting procedures, and errors were noted in performing system operations.[83]

In the area of survivability, FDDS and JOTS received evaluations of SAT, although testing was conducted only to a limited degree. COMOPTEVFOR observed that TFCC/FDDS was no more or less vulnerable to battle damage than other systems operating in the shipboard environment. However, that conclusion was made with the caveat that testing was conducted in a non-combat environment, and the system was not subjected to EMP or ECM.[84] JOTS I testing revealed no deficiencies either. However, in this case, testing the system for EMP effects was not an operational requirement of the system.[85]

Although no actual testing was performed to evaluate JOTS survivability against a conventional threat, the single JOTS systems installed aboard the USS STARK and USS ROBERTS proved very survivable against the shock and vibration from a single air-to-surface missile and mine attack in the Persian Gulf.[86] While on patrol in the Persian Gulf, the USS ROBERTS struck an Iranian mine which knocked out much of her electronics with the exception of its Hewlett-Packard computer. In a separate incident, the USS STARK while on patrol in the Persian Gulf was struck by an Exocet missile that cracked her Combat Information Center displays, putting her combat systems out of operation. Within that same

compartment, the Hewlett-Packard computer was found to remain operational.[47]

Important to system survivability were the effects of EMP. COMOPTEVFOR stated that EMP testing was a limitation to scope in its testing, and therefore was not evaluated. Nonetheless, the effects of EMP must be a considered. The information regarding this subject was beyond the classification of this thesis, but is available in other sources.

Discussed to a limited degree in the FDDS OPEVAL report was system survivability when operating in a degraded mode. COMOPTEVFOR tested FDDS under degraded operations by denying the tactical commander access to incoming information from ashore facilities and intracommunications within the battle group and simulated loss of two terminals. Voice circuits and other communication modes provided the means of keeping the tactical commander abreast of the situation. The additional results of this simulated testing were classified, but the information may be found in the FDDS OPEVAL report.[48]

System interoperability was evaluated by assessing how well FDDS and JOTS I operated with other Navy systems that included shore-based facilities and other shipboard systems. COMOPTEVFOR observed that FDDS demonstrated satisfactory performance in operating with both Navy shore and shipboard systems without problems.[49] JOTS I did not

interface with the Officer in Tactical Command Information Exchange System (OTCIXS) communications net adequately.[90] When problems were observed with OTCIXS communications, it caused JOTS I to generate software faults intermittently. The cause for the problem was unknown and required further investigation in COMOPTEVFOR's recommendations.[91]

Operational suitability also included a personnel side which considered the human factors aspect. COMOPTEVFOR's evaluation of human factors deficiencies was based upon subjective observations, and both systems were evaluated as unsatisfactory. The FDDS system was installed such that the printer was not located in the immediate vicinity of the operator for retrieval of paper products. Additionally, the installation did not allow easy access by personnel performing preventative and unscheduled maintenance.[92]

The human factors problem was different in JOTS I and focused on the man-machine interface aspect related to the software. The JOTS I functions were primarily menu driven by layers upon layers of submenus in different partitions of the system. Determining the status as well as operating in any partition required extensive knowledge of getting around the software to access information or troubleshoot software problems.[93]

COMOPTEVFOR evaluated the safety features of both FDDS and JOTS I as unsatisfactory. FDDS was safe for

operator use but unsafe to maintenance personnel. The latches housing the computer disk were designed such that maintenance personnel could injure themselves from the frame's sharp metal edges in attempting to gain access to the storage area. JOTS I was potentially a physical and electrical hazard to personnel at or near the terminal. Components were not mounted or secured to racks, and cabling was not contained within cable conduits nor placed under deckplates.[94]

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CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The hypothesis of the first subproblem is that the new DOD procurement policy is better than the old one in terms of streamlining the acquisition cycle and associated costs. I conducted analysis which included the DOD management and organization for procurement; DOD directives and instructions; the use of mil-specs versus commercial item descriptions and the threat. I reached the following conclusions.

The acquisition process was improved and streamlined. Recognition of the problem was brought to light by government studies to analyze the DOD's methods of business practice. The studies did in fact identify a significant problem in DOD's procurement organization and management. The Fitzhugh, Grace, and Packard studies conducted in the 1970's to 1980's identified the magnitude of the procurement problem. The lessons learned by the DOD in the Fitzhugh study were relearned as evidenced in subsequent Grace and Packard studies. In addition, the DSB studies conducted in 1978 and 1987 brought to light the specific problems of command and control systems procurement.

Implementing changes to deeply rooted procurement problems was a slow and tedious process. Because the DOD was a conglomeration of organizations that worked independently of one another, it was that much more difficult to resolve. In making administrative changes that cut across the board of the DOD and by establishing additional staff positions within OSD to oversee procurement two major steps were taken to solve some of the problems. The government studies repeatedly reached conclusions that recommended improving the acquisition management organization. DOD made changes to its directives and instructions to provide program managers the necessary guidance to do their jobs.

Following the administrative restructuring and reorganization, the DOD next re-educated its program managers. (Program managers needed to re-evaluate their decision-making process by breaking away from the old practice of buying new systems and attaching every conceivable item with a mil-spec.) The overuse of mil-specs and mil-stds, another deeply rooted problem, plagued program managers. DOD directives included recommendations that the tour length for program managers be increased. Thereby increasing their overall corporate knowledge in both the management and technical aspects of procurement.

The second hypothesis was that COTS computer equipment employed in a tactical environment to support the

Naval Commander afloat met his operational requirements but did not meet the military standards promulgated under the new procurement policy.

JOTS I did not meet the operational requirement of the tactical commander. Although it surpassed FDDS in hardware and software capabilities, JOTS was not significantly better than FDDS in supporting the tactical commander's C3I operational requirements. Those effectiveness and operational issues better suited to meet the requirements of the tactical commander in JOTS were offset by poor logistic supportability, inadequate compatibility and interoperability when compared to the FDDS. JOTS I did provide TDA's not available in FDDS and did prove to be an invaluable planning tool for the tactical commander in his decision-making.

In fielding a rapid prototype system such as JOTS I, there were some obvious tradeoffs identified in using COTS computers in technical performance, operational effectiveness and suitability. In COMOPTEVFOR's conclusions, both systems were evaluated as having the potential to be operational effective and suitable once corrections to those deficiencies were corrected.

Recommendations

This thesis covered an important period in time in which the US Navy focused it attention to a Soviet threat. With the collapse of the Soviet Union, reshaping of the

military, and the US Navy's role today, I recommend the following for further study.

The potential for military involvement in regional conflicts is probably the most likely. Further study of how to use C3I systems in a low intensity conflict environment should be investigated.

With the advent emerging new technologies in software, the likelihood of the viruses infecting software will probably also increase. The impact of such an occurrence could seriously impair C2 operations at any warfighting level. This potential threat warrants further study in determining measures of countering it.

In that same spirit of countering the effects of viruses, further study should be conducted to develop more effective counter countermeasures in denying enemy access to their C3I systems while protecting our own.

Finally, Desert Storm demonstrated to the military that combining forces in a joint effort provided a synergistic effect in combatting the enemy. As the US military places greater emphasis in joint operations, further research should be conducted to improve interoperability of Navy C3I systems in a joint environment.

APPENDIX A

TABLE I

JOTS CHRONOLOGY

Project Name	DT&E Date(s)	OT&E Date(s)
K310-5	Jul 88	Aug 88
JOTS I IOT&E	Jun-Jul 89	Aug 89

NOTES:
Data extracted from JOTS TEMP dated 18 August 1989.

TABLE II

TFCC CHRONOLOGY

Project Name	DT&E Date(s)	OT&E Date(s)
MSPS	May-Jun 74	
OUTLAW SHARK	Jan-Mar 75	
FCC/TFCC Ph I	Aug-Sep 75	
IFCC/ITFCC Ph I	Jun 76 - Jul 77	
TFCC	Oct 80	Oct-Nov 80
TFCC/FDDS*	Sep 81	Sep 81
TFCC/FDDS (OPEVAL)	Mar-May 84	May-Jun 84
TFCC/FDDS**	Apr 86 - Jun 87	Jul 86- May 87

NOTES:

DT&E data extracted from TFCC TEMP 240-2 III-2 dated 10 Aug 1989. OT&E data extracted from NTCS-A TEMP 1376 Annex D dated 13 Nov 1992.

* DT and OT were combined to take advantage of economy of resources.

** Incremental testing was performed to correct discrepancies identified during OPEVAL.

TABLE III

THRESHOLDS

Technical Characteristics	FDDS	JOTS I
System initialization	3 min	<25 min
System recovery	3 min	< 5 min
Track record capacity	500	1000
Ambiguity record capacity	200	250
Hard copy	40 sec	60 sec
Suitability Objectives	**FDDS**	**JOTS I**
Maintainability		
MTTR	1 Hr	1.5 Hrs
MTTR-O	4 min	1.0 Hr
Reliability		
MTBMCF (HW)	720 Hrs	500 Hrs
MTBMCF (SW)	4 Hrs	15 Hrs
MTBF (HW)	72 Hrs	250 Hrs
Availability		
A_o	.98	.90

NOTES:

Data for Table II were extracted from JOTS TEMP 240-10 dated 10 Aug 1989 and Operational Evaluation of TFCC report dated 07 Jan 1985.
MTTR - Mean Time to Repair
MTTR-O - Mean Time to Restore-Operator
MTBMCF - Mean Time Between Mission Critical Failure
A_o= Uptime / Uptime + Downtime (MTTR + Mean Logistic Down Time)

TABLE IV

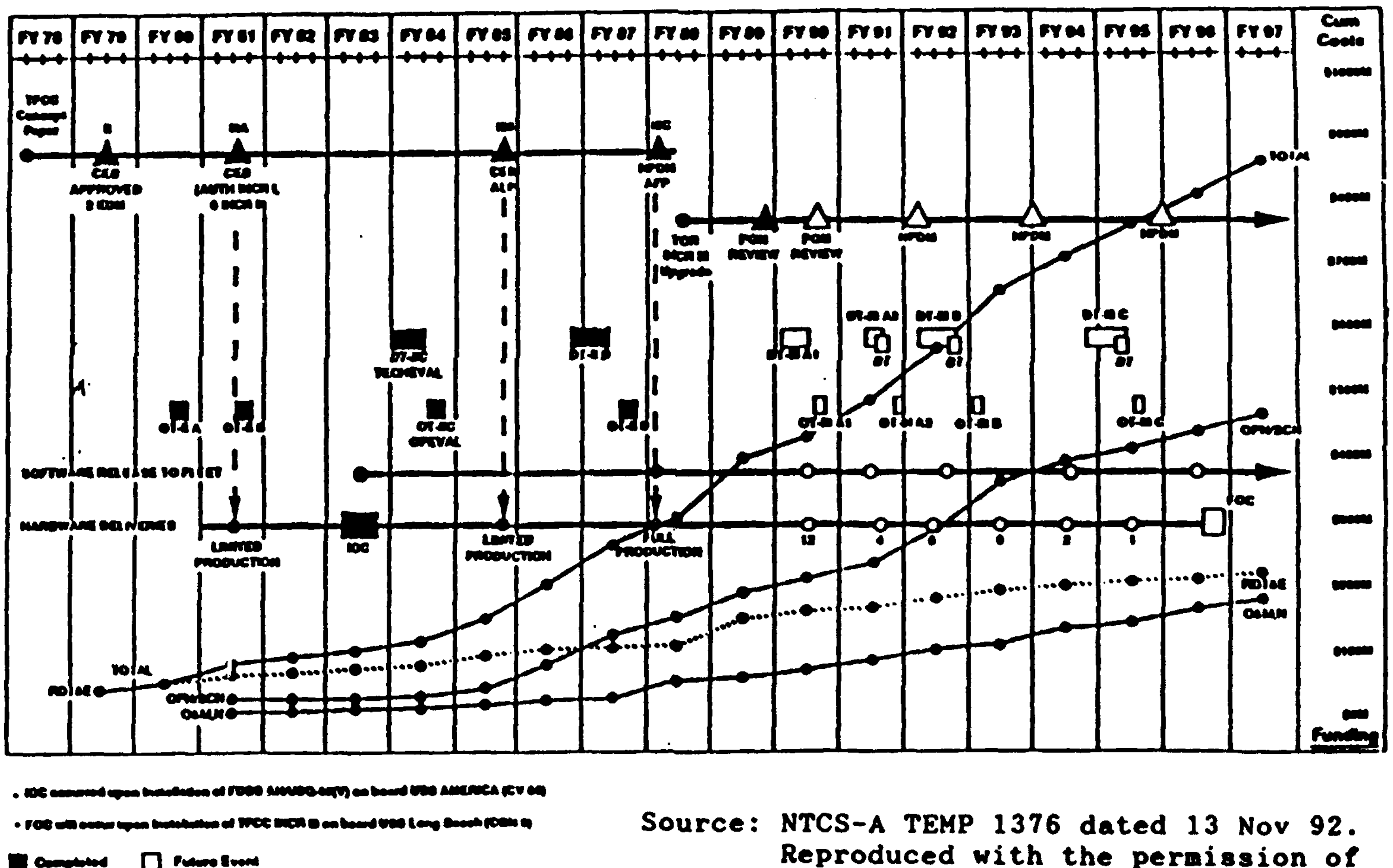
TEST OBJECTIVES

Effectiveness Objectives	Results FDDS	Results JOTS
OTC/BG Cdr support *	UNSAT	UNSAT
C2 Effectiveness *	UNSAT	UNSAT
Information Exchange **	UNSAT	UNSAT
Afloat correlation ***	UNSAT	UNSAT
Data Base Management	UNSAT	SAT
Tactical Decision Aids	N/A	SAT
Security	N/A	UNSAT
Suitability Objectives		
Maintainability	Unresolved	SAT
Reliability	SAT	SAT
Availability	UNSAT	SAT
Logistic Support	SAT	UNSAT
Compatibility	SAT	UNSAT
Interoperability	SAT	UNSAT
Training	UNSAT	UNSAT
Human factors	UNSAT	UNSAT
Safety	UNSAT	UNSAT
Documentation	UNSAT	UNSAT
Vulnerability	SAT	N/A
Survivability	SAT	SAT

NOTES:
FDDS results were extracted from NTCS-A TEMP 1376.
JOTS results were extracted from JOTS OT&E report 19 Feb 1991.
JOTS equivalent was called the following:
* Afloat Cdr Support
** Communications Information Processing
*** Attribute Matching

TEMP 240-2
May 1990

PART II. INTEGRATED SCHEDULE
TFCC



Source: NTCS-A TEMP 1376 dated 13 Nov 92.
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Figure 1

TEMP NO. 240-10
10 July 1989

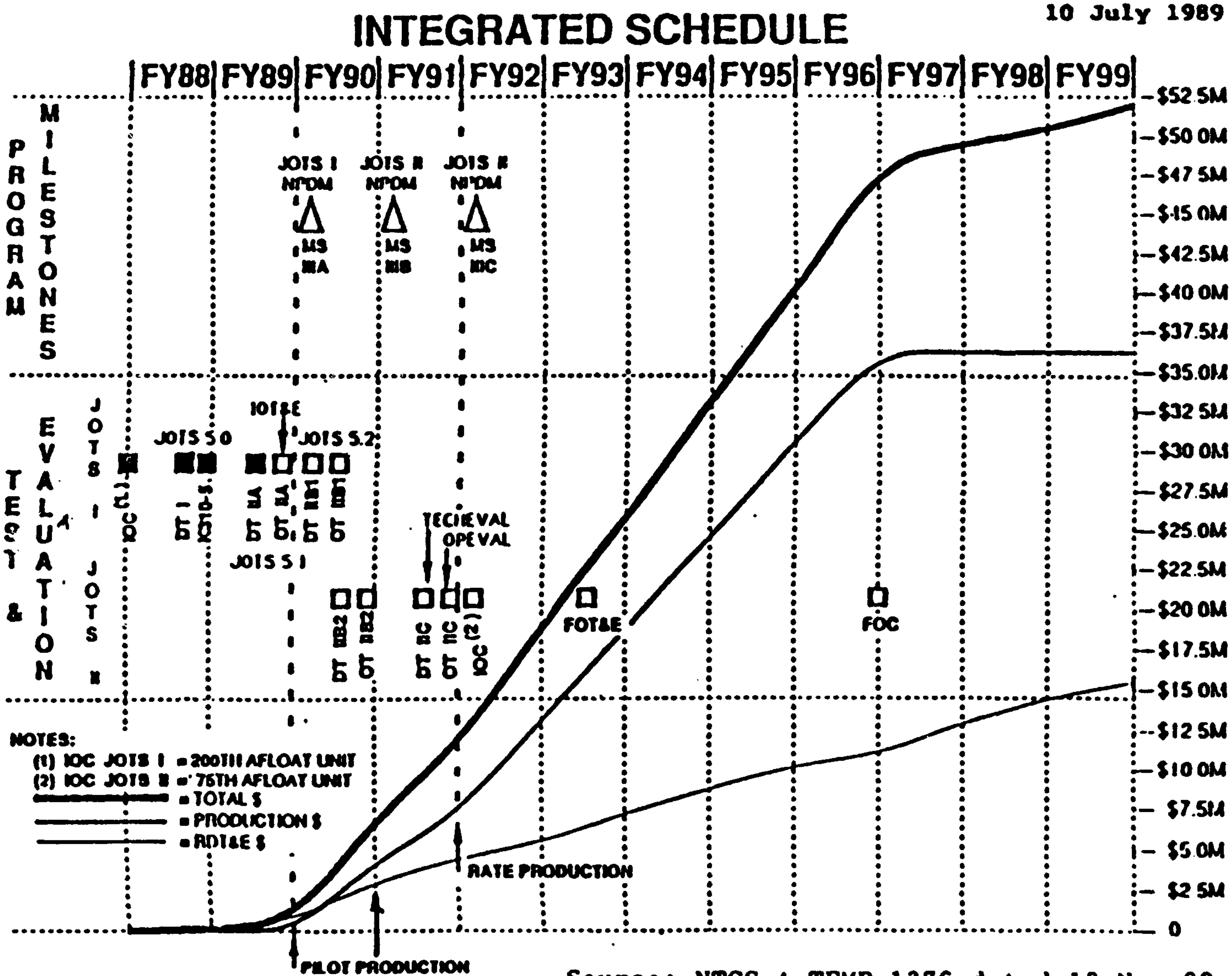

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Figure 2

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